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Feasibility of Floating Photovoltaics in the City of Bengaluru

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Abstract - *Floating Photovoltaics (FPV) is one of a kind technology which is said to be more beneficial than the conventional Solar Photovoltaics (SPV). There is also a growing need for potable water in metropolitan cities due to constant increase in population and also depleting water reserves due to various reasons. Henceforth, this paper deals with the feasibility of FPV in the city of Bengaluru. The main aspects for consideration here is a prediction model of the potential energy that can be produced for a 1 MW FPV plant on the Hesaraghatta lake in Bengaluru. An approximate of the amount of water that can be saved from the putting up of the FPV on the Hesaraghatta lake is also made in this report as part of the pilot project. The final statistical data of energy obtained are verified in connection with the PVsyst® and PVWatts® software for substantiation. A total energy of 1586 MWh of energy is obtained from the FPV as against 1539 MWh from SPV annually. Also PR is about 73.63% for FPV while SPV has a PR of about 71.48%. The CUF of FPV is 18.12% as against 17.59% of the SPV plant on for the Bengaluru city, over the water surface of Hesaraghatta lake. An estimated 81.586 million liters of water is saved by stationing FPV on the Hesaraghatta lake. Also to be mentioned is the estimated cost of stationing a FPV at Hesaraghatta lake is found to be around 7 crore Indian rupees and a payback period of about 5 years with an energy cost of around 8 Indian rupees per KWh.*

Key Words: Photovoltaics, SPV, FPV, module temperature, PR, CUF, evaporation rate.

1. INTRODUCTION

The ejection of electrons from a metal surface when it absorbs the electromagnetic radiation is termed as photovoltaics effect. This concept paved way for the production of solar cells and is being used even today to generate electricity. The use of such solar cell modules on land is quite familiar, also called Solar Photovoltaics (SPV). The solar modules can be used on the water surfaces which is termed as Floating Photovoltaics (FPV). FPVs are said to be more effective and more efficient producer of electricity than its predecessor which is the SPVs [1]. We know that the module temperature plays a major role in the efficiency of a PV module; the more the temperature, the lesser the efficiency. Henceforth, because of the soothing effect of the water bodies on the cell temperature and module as a whole, the FPVs are more sought after than the SPVs [2]. There is a huge potential of FPVs on potable water bodies, be it lakes, ponds and reservoirs as it reduces evaporation rate and gallons of water is saved [3].

The lake considered here is the Hesaraghatta lake. There are a plenty of lakes here in Bengaluru, in fact it was called the city of lakes in its early days of inception. A Bengaluru Municipal Corporation data reveals a record 262 water bodies in Bengaluru till 1960. The figures have gone down drastically to 81 of which only 34 have been recognized as live lakes today. These stats mark a reduction of water bodies as high as 35%, while with respect to water spread area it shows a decrease of 8.6%. Add to this is the population of the Bengaluru which is growing at a swift rate from 8 million people in 2001 to 12 million odd in 2017 only in its urban locales. All these staggering figures highlights the need for fulfillment of water to this ever growing human population in such cities [4]. This paper involves the prediction model for 1MW solar power plant on the surface of the Hesaraghatta lake using collection of weather data from various sources and involves manual calculations based on several journal papers to bring the possible power production and power utilization factor for the year 2017. Consequently, the SPV's production factor is compared and the adaptability of FPVs are to be brought about. Also the Evaporation rate is calculated to estimate the total water that could be saved by the erection of the FPVs on the Hesaraghatta lake. Subsequently the statistics of power production are brought about with a simulation software called PVsyst to check with the calculated values. Also an approximate cost estimation of 1MW FPV plant is made.

1.1 Photovoltaics on Water

FPV system is made out of floating systems, mooring systems, PV systems, cables and connectors. Fig. 1 gives the schematic of a FPV system. The floating system consists of floaters or floats which help the PV modules stay on water. The mooring system helps the FPV not to sail because of the waves and other adversities of water. The PV system includes structures, PV modules and other power molding gadgets to enhance the productivity. There is also cables and connectors for easy transmission of power. As said earlier, FPVs are more advantageous than SPVs and also have very little effect on the environment.

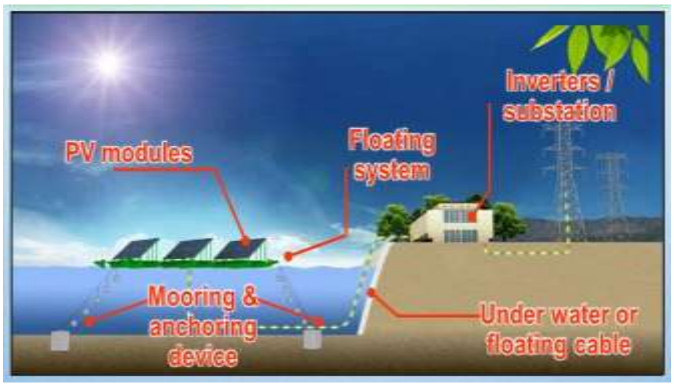

Fig -1: Schematic of FPV system

1.2 City of Bengaluru for the Study

Bangalore, formally the Bengaluru, is the capital of the Indian state Karnataka. Bangalore is situated in the southeastern district on the state on the Deccan Plateau, and it is the third most crowded city and the fifth most crowded urban region. Bangalore has an estimated population of 12.34 million in its urban area in 2017, up from 8.5 million in 2011 [6] [7].

21 Indian cities – including Delhi, Bengaluru, Chennai and Hyderabad – will run out of groundwater by 2020, affecting 100 million people; 40 percent of India's population will have no access to drinking water by 2030, says the 'composite water management index' report [8].

Hesaraghatta lake is projected for rejuvenation under the 'yettinahole' project of the Government of Karnataka to cater to the water needs of the city [9]. Hesaraghatta lake is located 13.15degree North latitude and 77.49degree East longitude and holds potential to save millions of liters of water. This paper will try and predict the volume of potable water that can be saved. Fig. 2 shows the satellite image of Hesaraghatta lake in Bengaluru taken from google.

Fig -2: Satellite picture of Hesaraghatta lake at Bengaluru taken via google.

2. ENERGY PRODUCTION ESTIMATION TECHNIQUES

The amount of energy produced using any photovoltaic module can be found out by first finding the total solar radiation on the tilted PV module, then the array losses like the radiation loss, temperature loss and so on are taken into consideration before finding out the possible maximum energy that can be generated. Finally, after inverter and transmission losses the energy fed to the grid can be found out.

2.1 Solar Radiation on the Tilted (inclined) Surface

Sunlight based irradiance got straightforwardly from the Sun with no deviation is called direct or shaft irradiance. The irradiance got in the wake of being dissipated by barometrical particles is called diffuse irradiance. The entirety of direct irradiance and diffuse irradiance is called worldwide irradiance as appeared [10]:

$$I_g = I_b + I_d \quad (1)$$

Where Ig is global irradiance, I_b is beam irradiance, and I_d is diffuse irradiance.

$$I_b = I_g - I_d \quad (2)$$

The solar radiation received on Tilted surface, I_T of the PV array is given by [11]:

$$I_T = I_b r_b + I_d r_d + (I_b + I_d) r_r \quad (3)$$

Dividing both sides by I_g Equation (3) becomes,

$$I_T = [(1 - I_{d/}I_g) \times r_b + I_d/I_g\, r_d + r_r] \times I_g \quad (4)$$

Where, r_b is the tilt factor for beam radiation, r_d is the tilt factor for diffuse radiation and r_r is the tilt factor for reflected radiation from the ground surrounding the array. These are calculated as:

$$r_b = \cos\theta/\cos\theta_z,\ r_d = 1+\cos\beta/2 \text{ and } RR = \rho(1-\cos\beta/2) \quad (5)$$

Where, ρ is the reflectivity of the ground.

The angle of incidence of solar radiation at collector surface is given in [12]. When collector is south facing then the angle of incidence is given by [13]:

$$\cos\theta = (\cos\varphi\cos\beta + \sin\varphi\sin\beta\cos\gamma)\cos\delta\cos\omega$$
$$+ \cos\delta\sin\omega\sin\beta\sin\gamma + \sin\delta\,(\sin\varphi\cos\beta - \cos\varphi\sin\beta\cos\gamma) \quad (6)$$

However, when the PV array is south facing (γ=0) then (6) becomes:

$$\cos\theta = \sin\delta\sin(\varphi - \beta) + \cos\delta\cos\omega\cos(\varphi - \beta) \quad (7)$$

And

$$\cos\theta_z = \sin\varphi\sin\delta + \cos\varphi\cos\delta\cos\omega \quad (8)$$

where θ is the incidence angle, φ is the latitude of the location, β is tilt angle, γ is azimuth angle (γ=0 for surface facing due south), ω is hour angle, and δ is declination angle given by [14]:

$$\delta = 23.45 \times \sin[360/365 \times (284 + n)] \quad (9)$$

In which "n" is the day of the year.

2.2 Losses in the Array

a) Solar radiation losses: This is an adversity which happens because of impression of PV modules from the outside of the glass. It regularly extends from 2%-4% [15]. Weakening of the radiation likewise happens because of transmission in expansion to reflection. This misfortune is named as the irradiance misfortune or Incidence Angle Modifier (IAM) misfortune. It complies with Fresnel's law and [16] demonstrates its estimation. In this paper the radiation loss is considered to be 3% [15].

b) Module mismatch losses: These misfortunes experienced because of the distinctive I-V qualities of same evaluated PV modules, when associated in arrangement and parallel. The assembling resilience of PV modules yield power is +/ - 3% [15]. [17-20] gives us the various strategies that can be utilized for assessing and decreasing such misfortunes in an exhibit. In this paper, jumble misfortune factor is taken to be 1% [16].

c) DC cable loss: The DC cables loss refers to the resistive losses that takes place in the cables connecting the modules. The losses are represented by a resultant resistance of the PV array. [16]. The cables' thickness is usually designed to keep the losses within 2% [15]. For this study the losses are taken to be 2%. [15].

d) Temperature loss: The temperature losses represent the losses due to PV modules operating above 25 °C. This is calculated by finding the cell temperature. [21] shows the different models for the cell temperature calculation and also the temperature losses calculations. This paper utilizes:

$$T_{cell} = T_{ambient} + (T_{NOCT} - 20/G) * I_g \quad (10)$$

Where, T_{cell} is the cell temperature, $T_{ambient}$ is the ambient temperature, T_{NOCT} is the nominal operating cell temperature and G is the solar radiation at which NOCT is defined= 800W/m2. Knowing this parameter, temperature losses in a PV module can be estimated [21].

e) Module quality loss: The performance of a PV module gradually varies from the specifications that were given by the modules manufacturer with time and such variation in the performance of the PV module is represented as the module quality loss. This factor is taken as 0.8% in this paper [16].

2.3 Energy Calculations

a) Maximum possible energy produced, E_{max}: The maximum possible energy from the plant can be estimated by multiplying the plant installed capacity and the daily solar radiation data received on the plane of array. Monthly energy production: [15]

$$E_{max} = \text{Plant Capacity} \times \text{Average sunshine hours} \times \text{number of days in a month} \quad (11)$$

b) Array energy after considering losses, E_a: The losses in the array are applied on the maximum possible output to estimate Ea [15].

$$E_a = E_{max} \times [1 - \text{operating losses in the array (\%)} \quad (12)$$

c) Energy fed to the grid, E_{grid}: The output generated E_a, then flows through the input of the inverter in DC form where it is converted into AC. The inverter also performs the function of maximum power point tracking (MPPT). The output energy from the inverter will be lesser than the input energy due to inverter losses. Inverter loss factor of 4.8% is considered here. [22] Output from the inverter is transferred to the grid through AC cables. Some losses occur in AC cables too. The loss is usually small less than 1%.

$$E_{grid} = E_a \times [1 - (\text{Losses at inverter (\%)} + \text{loss in AC cable(\%)})] \quad (13)$$

2.4 Annual PV Performance Ratio (PR) and Capacity Utilization Factor (CUF)

The annual Performance Ratio (PR) is defined as the ratio of energy supplied to the grid, E_{grid}, to the rated power and the solar radiation received by the tilted surface, I_T, to the standard global irradiance, I_o, which is1000 W/m^2. The Capacity Utilization Factor (CUF), on the other hand is defined as the ratio of energy supplied to the grid to the PV plant installed capacity. The calculation for PR and CUF are done for the comparison of the performance of PV plants and are done as follows [23]:

$$PR = E_{grid}/P_o/I_T/I_o \quad (14)$$

$$CUF = E_{grid}/24 \times 365 \times \text{PV Plant Installed Capacity} \quad (15)$$

Where P_0 is the rated power.

3. EVAPORATION RATE CALCULATION

Dissipation of water from a water surface such as a lake, a reservoir or ponds - relies upon water temperature, air temperature, air moistness and air speed over the water surface. The amount of evaporated water can be expressed as [24]:

$$g_s = \frac{\Theta A (x_s - x)}{3600} \quad (16)$$

Where,

g_s = amount of evaporated water per second (kg/s).

$\Theta = (25 + 19\,v)$ = evaporation coefficient (kg/m^{2}h) (17)

v = velocity of air above the water surface (m/s).

A = water surface area (m^2).

x_s = maximum humidity ratio of saturated air at the same temperature as the water surface (kg/kg) (kg H_2O in kg Dry Air).

x = humidity ratio air (kg/kg) (kg H_2O in kg Dry Air).

The saturation pressure of water vapour at the actual temperature is given by [131]:

$$x_s = \frac{0.62198\ p_{ws}}{(p_a - p_{ws})} \quad (18)$$

Where,

x_S = maximum saturation humidity ratio of air (kg_{water}/kg_{air}, lb_{water}/lb_{dry_air}).

p_{WS} = saturation pressure of water vapour.

Specific humidity (*x*) is found out using the Mollier's chart provided the ambient temperature and the relative humidity or the moist temperature [24].

4. METHOD CONSIDERED

MS Excel is used for performing the energy calculation for a 1MW SPV and 1MW FPV solar power plants in Bengaluru, Karnataka India. At the first, the solar radiation data are taken from the NREL, National Solar Radiation database. With the help of these data the various solar angles are calculated, followed by the calculation of the solar radiation, energy from the array, energy supplied to the grid and other parameters which are needed. Fig. 3 shows the different steps involved in the calculation of energy and finally the evaporation rate is brought out with cost estimation for an FPV.

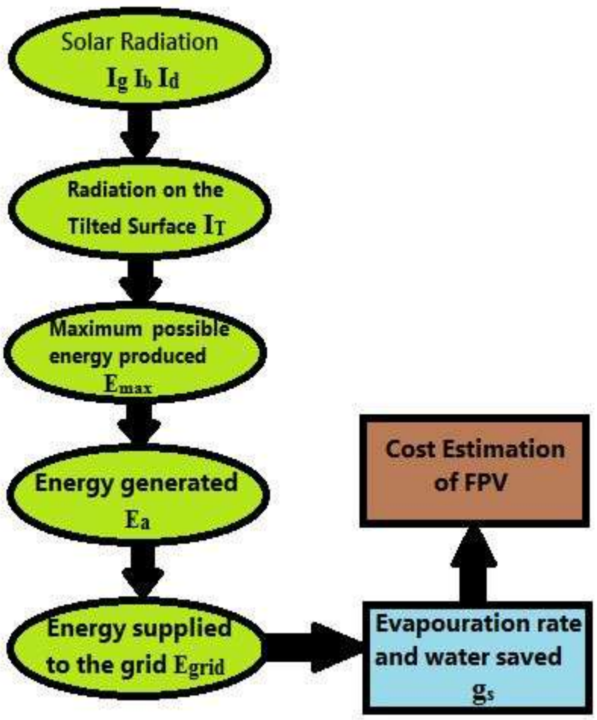

Fig -3: Flow chart depicting the method followed.

The solar angles are calculated at the mid-time interval and the PV array are assumed to be south facing (hence γ=0). All the parameters calculated are assumed for maximum power point operation [13]. 320W Phono Solar Technology multi-crystalline PV modules having standard efficiency of 16.47% and module area of 1.94 m2 and Schneider Electric Solar inverters of 100 kilo WAC are selected considering inverter loss factor of 4.8%. [25] The energy calculations for FPV power plant is performed in the same way considering 5degree Celsius temperature difference between the water surface and the ground [26], [27]. The losses calculations are done in the same as that of the SPV power plant and a calculation for evaporation is done with the help of [24].

Calculations of solar angles take place in the first step using empirical equations and then radiation on the tilted surface is calculated. In the maximum energy output is bought out without considering any kind of losses. After consideration of losses like temperature loss and array losses the energy output from the solar PV array is tabulated. After the consideration of inverter and cable losses the energy that could be fed to grid can be recorded. Finally, the evaporation rate is calculated using [131]. The cost estimation was made using [28] and using data from local authorities of the Bengaluru city corporation payback period is brought out.

Also to be mentioned is the monthly ambient temperature data for the year 2017 was found out using PVGIS ©European Union database [29]. The wind speed data for the year 2017 was also found form the data base of the PVGIS, European Union Database [29] and renewables ninja web portal [30]. The wind speed data given was on an hourly basis for 365days for the year 2017 which was averaged for a monthly data has been put forth in this paper.

5. RESULTS AND DISCUSSIONS

The approximation of the amount of the global horizontal radiation for the city of Bengaluru is found to be 2870 kWh/m^2 for the year 2017 which has been calculated using various sources and empirical equations. Also, the radiation on the tilted surface is found in the same way and is noted at 2960 kWh/m^2 for the same year. The titled angle is assumed to be same as the latitude [31]. Chart -1. depicts the solar radiation distribution round the year for 2017 with both global and tilted irradiance for the city of Bengaluru, Karnataka, India. Overall the radiation on the tilted surface is more because of more exposure to the Sun.

The plant will require 3,125 numbers of 320 W Phono Solar Technology multi-crystalline PV modules and 11 numbers of 100kW Schneider Electric Solar inverters. Chart -2. shows the energy generated by the power plant monthly before feeding it to the grid E_a. The highest being in the month of March which is 164.27 MWh and the lowest being in the month of July which is 111.8085 MWh. This measure is done with the consideration of all the losses involved as discussed before in this report. This output energy is in particular for Bengaluru which is to be compared with the FPV in this same paper.

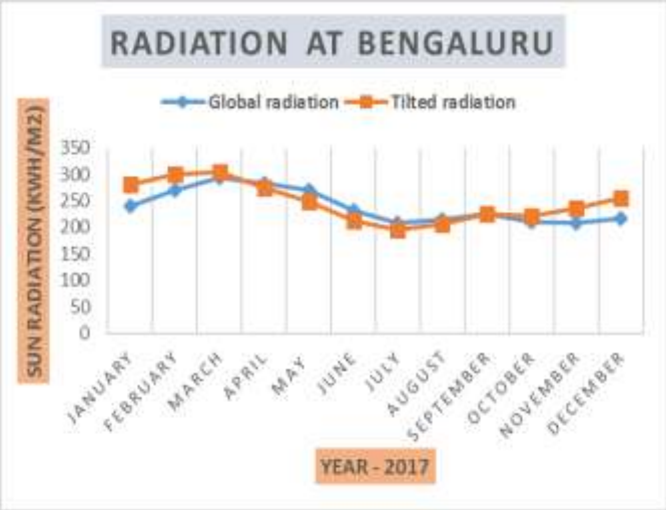

Chart -1: Solar radiation in Bengaluru city for the year 2017

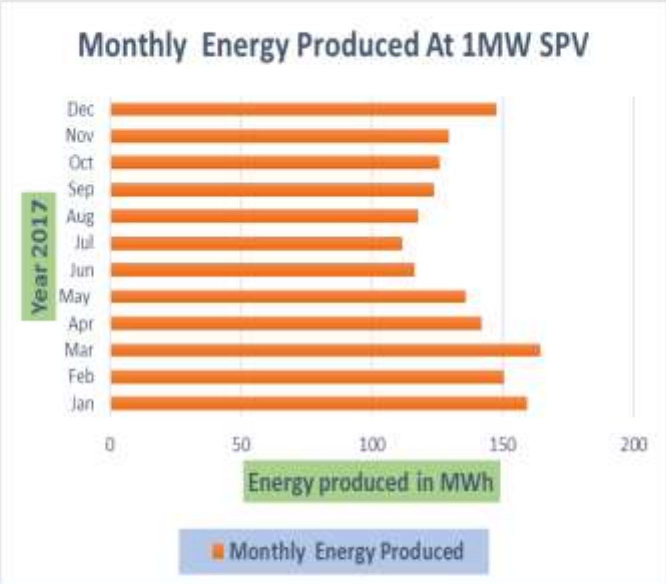

Chart -2: Energy generated by 1MW SPV at Bengaluru for 2017

Chart -3. depicts the monthly variation in the Performance ratio (PR) of the 1 MW SPV plant in Bengaluru. The performance ratio is found to be the highest in the month of December 2017 which is about 76.56%. The lowest PR in the month of April which comes to 68.29%. This clearly indicates that the performance is top notch during the summer. The module temperature is highest in the month of April at 34.21 degree Celsius and lowest in the month of December at 24.17 degree Celsius. It is also contrasting to note that highest energy supplied to the grid is in the month of march at 32 degree Celsius with a whopping 155 MWh. The least energy supplied is in the month of July which is 105 MWh with a module temperature of 24 degree Celsius. Also the highest CUF is in the month of February with 21.22 % and least in the month of July with 14.23 % as shown in Table -1.

Chart -3: PR of 1MW SPV at Bengaluru for 2017

Table -1: Characteristics of 1MW SPV

Months	Ambient Temperature T_a (°C)	Module Temperature T_m (°C)	E_{grid} in (MWh)	PR (%)	CUF (%)
January	22.5	26.47	151.08	72.31	20.30
February	24.9	29.10	142.60	70.54	21.22
March	27.5	32.43	155.60	68.85	20.91
April	29.4	34.21	134.60	68.29	18.69
May	27.4	31.81	128.73	69.44	17.30
June	23	25.99	110.40	72.29	15.33
July	22.3	24.98	105.90	73.15	14.23
August	23.1	25.82	111.48	72.65	14.98
September	23.2	26.27	117.46	72.37	16.31
October	24.5	28.17	119.26	72.18	16.03
November	24.6	27.95	122.54	72.16	17.01
December	20.9	24.17	139.79	73.56	18.79

The FPV plant on the water surface of the Hesaraghatta lake produces 169.4 MWh of energy in the month of March which is the highest and least being 115 MWh in the month of July. The Chart -4. depicts the energy production by FPV in different months of the year.

The Performance ratio on the other hand seems to be just right with 75.71% in the month of December and 70.44% in the month of April. Overall it seems to be well above the SPV standards. The Chart -5. here depicts the PR of the 1 MW FPV for a year on a monthly basis. The chart also shows us that the performance is tends to go liner after June where there is little variation from then on. While there is drop down in PR from the 1st month of the year until April after which it picks up. So the summer months of 2017 were not suitable for the power generation using FPVs.

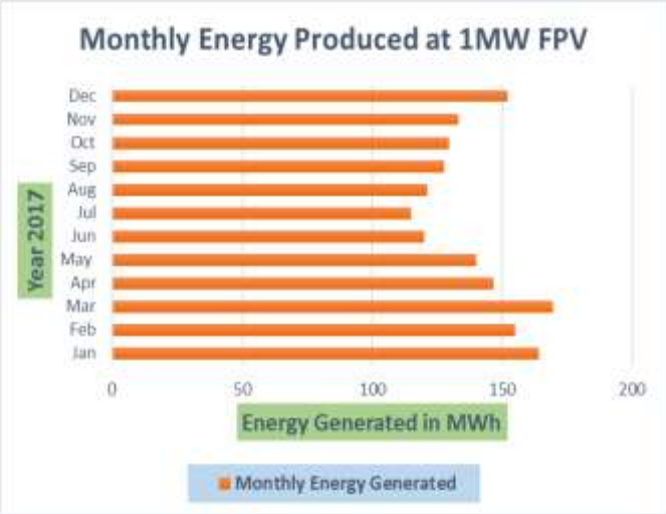

Chart -4: Energy produced by 1MW FPV for 2017

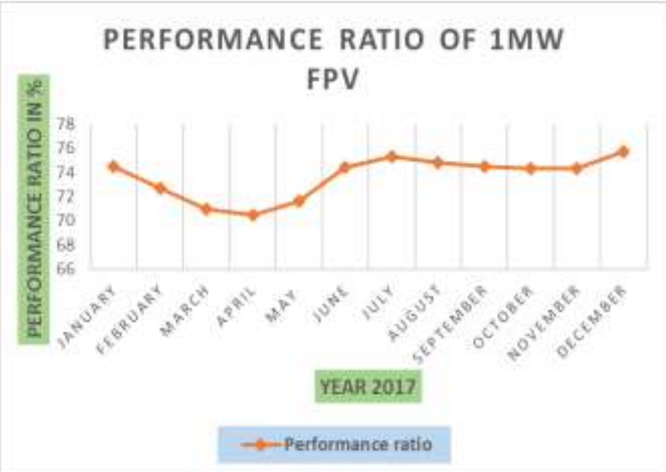

Chart -5: PR of 1MW FPV for the year 2017

The Table -2. gives us the Energy that is supplied to the grid after taking into consideration of the losses, say inverter losses, cable losses and so on. The maximum module temperature is slated to be in the month of April at 29.21 degree Celsius. The lowest module temperature stands at 19.17 degree Celsius which happens to be in the month of December. The highest energy supplied to the grid is in the month of March and least in the month of July. The highest CUF is noted at 21.86% in the month of February and least at 14.65% in the month of July.

The very major aspect which can be brought out in this prediction is the module temperature. The module temperature differs by a margin of around 19% between SPV and FPV. That approximately stands at a 5degree Celsius temperature difference. The Chart 6. shows us the distribution of temperature for one full year month wise. It can be noted from the chart that the module temperature of the FPV stands close to the ambient temperature while that of SPV is far above in the temperature profile.

Table -2: Characteristics of 1MW FPV

Months	Module Temperature T_m (°C)	$E_{grid\ in}$ (MWh)	PR(%)	CUF(%)
January	21.47	155.58	74.46	20.91
February	24.10	146.95	72.69	21.86
March	27.43	160.46	71.00	21.56
April	29.21	138.84	70.44	19.28
May	26.81	132.72	71.59	17.83
June	20.99	113.68	74.44	15.78
July	19.98	109.02	75.30	14.65
August	20.82	114.78	74.80	15.42
September	21.27	120.95	74.52	16.79
October	23.17	122.81	74.33	16.50
November	22.95	126.19	74.31	17.52
December	19.17	143.88	75.71	19.33

The highest module temperature for both SPV and FPV occurs in the month of April and lowest in the month of July. It seems that the PV modules work better when the module temperature is in close values of the ambient temperature. Chart 6. depicts the module temperature of SPV and FPV stacked up with the ambient temperature of the surrounding.

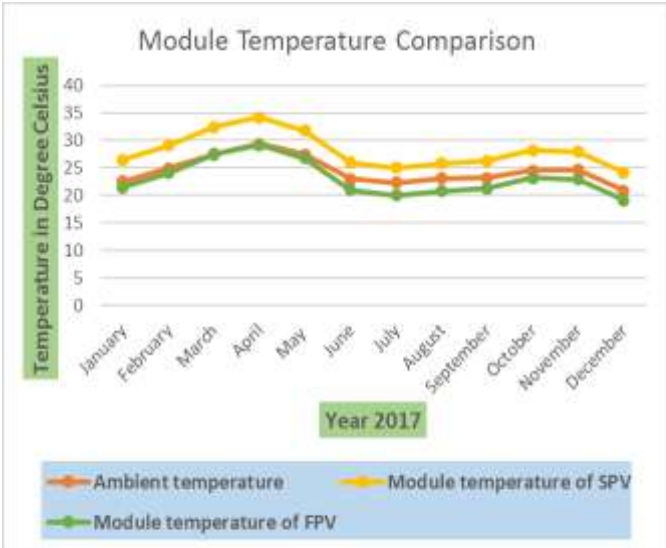

Chart -6: Module temperature difference between SPV & FPV

The energy generated by the FPV power plant is observed to be 3.012% higher than SPV power plant. The main reason is due to the reduction in the module temperature caused by the cooling effect of water in the FPV modules. The reduction in module temperature of FPV as compared to SPV power plant is calculated to be 18.88% annually. Chart -7. gives the monthly variations of the performance ratio of 1 MW SPV and FPV power plants respectively. Chart -8. shows the monthly variations in the capacity utilization factor of a 1 MW SPV and

FPV power plants at Bengaluru. The average energy produced by the FPV plant per month stands at 139.51 MWh while the SPV produces an average of 135.43MWh of energy in a month. Annually 1625.25MWh of energy is produced using SPV while a predicted 1674.23MWh of energy by the FPV.

Chart -7: PR comparison of SPV and FPV for the year 2017

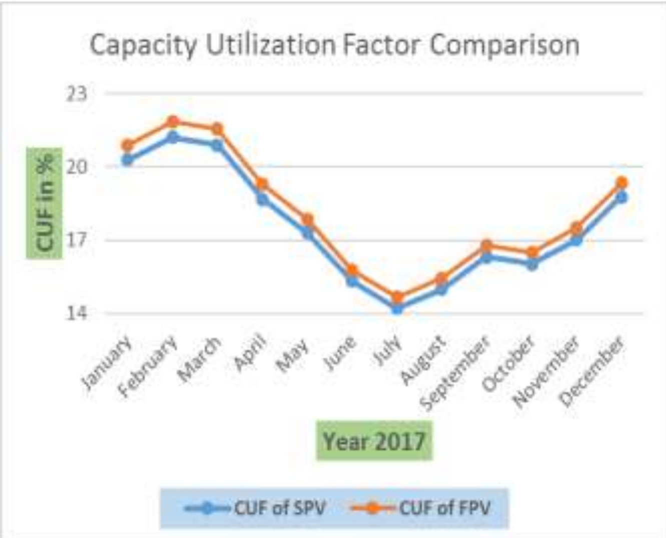

Chart -8: CUF comparison of SPV and FPV for the year 2017

The water surface area required for the erection of 1 MW FPV plant is approximately 1 hectare of the water surface [3]. The evaporation rate is calculated using methods described in [24] which involves data collection of the ambient temperature and the use of empirical equations to finally list out the monthly data of the water evaporated from the surface of the lake. The Fig 12. shows the variation of the evaporation rate for the year 2017 on a monthly basis. It is clearly seen that the rate of evaporation is very high between the months of February and April. April has the highest rate while July has the lowest rate of evaporation.

The Evaporation is subjected to 8 hours on an average per day [28] and accordingly the water in kg/second is calculated [24]. The use of Mollier's chart to determine the specific humidity ratio of moist air by first determining the values of saturation pressure of water vapour using empirical equations and relative humidity values from [29]. Finally, the amount of water that is evaporated from the free open space is approximately found to be 10642345.67 litres in the year 2017 at the Hesaraghatta lake for one hectare of the surface area.

Chart -9: Evaporation rate of water in Hesaraghatta lake

The PV panels would cover around 1-hectare surface of water and evaporation takes place for only 66.6% of the surface; as obvious about 30% of the evaporation is reduced; and then 70% of the 66% is reduced [28] [32]. Hence forth a solid 8158635.037 litres of water can be saved by the commission of 1MW FPV plant on the Hesaraghatta lake in Bengaluru Karnataka. The Table -3 depicts the overall comparison of FPV and SPV with all the major characteristics involved from energy production to water savings.

Table -3: SPV v/s FPV outcomes comparison

Parameters	SPV	FPV
Average Module Temperature (°C)	28.11	23.11
Energy fed to the grid, E_{grid}, annually (MWh)	1539.502	1585.901
Performance ratio (%) annually	71.48	73.63
Annual Capacity Utilization Factor (%)	17.59	18.12
Amount of Water saved per year(Million Litres)	0	81.586

The Table -4. gives us the estimate of the FPV plant according to a reference made in [28]. The rough estimate of 1MW fixed floating photovoltaic plant is tabulated below using [28]:

Table -4: Cost estimation of 1MW FPV plant

Components	Quantity	Costs(INR)
Raft Carpentry (number of rafts)	160	15400000
PE pipes (number of pipes)	640	12320000
PV modules (number of modules)	3125	32000000
Cable & Inverter	-	10780000
Site preparation	-	2310000
Work (hours)	3000	3080000
Total		7,58,90,000/-

In the limits of BBMP (Bruhat Bengaluru Mahanagara Palike) which happens to be the municipality concerned here for the Hesaraghatta lake, the tariffs for electricity laid out by the BESCOM (Bengaluru Electricity Supply Company Ltd.,) stands at 875 paisa per KWh [33]. Also the water charges for the Bengaluru city as laid out by the BWSSB (Bengaluru Water Supply and Sewerage Board) stands at 90 INR per 1000 litres [34]. The Table -5. gives an expected payback period for the fixed type FPV at Hesaraghatta lake, Bengaluru, Karnataka.

Table -5: Payback period calculation of 1MW FPV plant

	Costs (INR)
Capital cost for 1MW FPV	7,58,90,000/-
Money made by selling of energy produced/year in Bengaluru	1,38,76,639/-
Money made by selling of water saved/year in Bengaluru	7,34,277/-
Total Incoming funds per year due to FPV	1,46,10,916/-
It can be concluded that he payback period for the above data stands at 5 years.	

Payback period = Incoming funds per year/capital cost of FPV and it stands at around 5 years which is quite good a prospect.

6. CONCLUSIONS

The study and prediction model suggested here holds true of the fact that FPV power plants are the future with more efficiency due to the cooling effect of water on the Module temperature (23.11 ^{o} C). Henceforth the highest power generation with peak PR (73.63%) as well as CUF (83.2%) when compared to the SPV is obtained with FPV. It is very much applauded that there is considerable amount of water (say 81 million litres) is saved when FPV plant is stationed on the Hesaraghatta lake of Bengaluru, Karnataka, India. This lake is up for rejuvenation to cater to the thirsty needs of the Bengalurians and hope this paper would enable to sustain more potable water, not just to this city but to many others around the globe. The final cost estimation and approximate payback period for a FPV power plant is suggested at 5 years. The prediction model suggested here is definitely credible and can be inferred for various projects of the future. Also the energy generation values estimated here for both SPV and FPV are on par with software like the PVsyst® and PVWatts® (which was tested for). The PVsyst® software gave a tally of 1550MWh of power generation [29]; and the PVWatts® also gave a power generation of 1550MWh [35] which are in par with our prediction standing at 1539MWh.

The future prospects for this project activity involves to check for the environmental impacts of the FPVs on the marine life. It is to be checked whether the PV modules on water would attract birds; this would mean their defecation and other dirt over the panels potentially hampering the performance as well as the durability of the modules. Also to be checked for is the feasibility on dams or reservoirs as accessibility to these areas is an uphill task. The erection of FPVs can also hamper commercial activities like fishing and recreational activities if any. Also the act of waves and their impact on the FPVs has to be bought out categorically for the desired locations as the wave nature changes with latitude and longitude. So this is a paper with lot of future prospects.

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